

Central Intelligence Agency



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DIRECTORATE OF INTELLIGENCE

12 March 1985

Chinese Progress in the Production of Integrated Circuits

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Summary

One of Beijing's primary technology tasks is to develop a modern microelectronics industry that will enable China to produce for export as well as to meet its domestic requirements for electronic devices. Because many Chinese integrated circuits are unreliable and inefficient, Beijing now imports most electronic devices needed for key computers and military projects.

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China's present ability to produce integrated circuits lags behind the West by about 10 years. Devices are larger than their Western counterparts, require more power, and operate more slowly. Production problems include inadequate coordination between research and production units, limited availability of key pieces of quality-control and test equipment, and shortages of qualified midlevel engineers and managers.

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To remedy these deficiencies, China has begun a comprehensive reform of its R&D sector and an ambitious import program involving both complete production lines and key pieces of equipment. We expect these efforts to yield some significant

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results over the next few years. For Western firms attempting to sell to China's electronics sector, China's expansion plans have opened up significant sales opportunities. [redacted]

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Introduction

China's highest technological priority is to establish a modern semiconductor industry capable of supporting an expanded computer development and manufacturing program. By 1990 the Chinese hope to develop a capability in advanced microelectronics equal to the United States' capability in the early 1980s. China's objectives are twofold:

- To increase the sophistication of the devices produced domestically for use in advanced computers and in military systems.
- To boost the supply of medium-level electronic components available for use in dual-use computers and in consumer goods.

In the longer term, Beijing intends to become a major exporter of integrated circuits and a strong competitor in the international marketplace for sophisticated electronic components. To accomplish these objectives, China has shifted its electronics modernization strategy from one emphasizing self-reliance to one of importing advanced technology and equipment from the West and Japan to speed the pace of development and to cut R&D costs. [redacted]

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Growth of the Industry

China's integrated circuit industry had its beginning in early 1956, when the leadership formed a national committee to develop plans for the rapid development of semiconductor devices. During the late 1950s, China produced prototype semiconductor diodes and transistors. In the early 1960s, it began to develop a production capability for discrete semiconductor components, and by 1965 at least 34 factories and research institutes were making semiconductor materials and fabricating semiconductor devices. [redacted]

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Despite dislocations caused by the Cultural Revolution, the electronics sector continued to grow between 1966 and 1976, chiefly because of its importance to strategic weapons development. As part of a nationwide policy of dispersing defense-related production to shield industry from enemy attack, China during this period constructed additional semiconductor research and production facilities in remote areas of China. As a result of this effort, four major electronic research and production centers were established in China's interior (Gansu, Sichuan, Yunnan and Guizhou Provinces), in addition to the electronic production centers in Beijing, Tianjin, Shanghai, and

several coastal provinces. These interior production plants are relatively sophisticated and continue to produce primarily for military customers. By mid-1971, the number of Chinese plants known to be engaged in series, batch, or experimental production of semiconductor components had grown to 82--more than double the number identified in 1965. [redacted]

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In the late 1970s, China began a new push to acquire Western technology for the production of semiconductors and other sophisticated electronic goods. One major new production line for integrated circuits was planned during this period, a facility at the Jiangnan Radio Equipment and Materials Plant in Wuxi, Jiangsu Province. Production at the new plant has been held up by difficulties in obtaining US export licenses for needed new equipment, the need to refurbish some of the used equipment, and legal problems involving the US trade agent. When completed the Wuxi plant will for a time be China's largest integrated circuit factory, with a capacity of over 26 million linear integrated circuits per year. [redacted]

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With the backing of the Leading Group for the Invigoration of the Electronics Industry, formed in 1982 and renamed and reconstituted in 1984, other facilities of similar size are also planned for Tianjin, Shanghai, Beijing, Shaoxing, Changsha and several other cities. Combined output for these major projects could reach several hundred million integrated circuits per year. [redacted]

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Current Capabilities...

China's semiconductor industry today reportedly consists of more than 500 facilities, 200 of which are involved in some aspect of integrated circuit development and manufacture. The Chinese claim that the Ministry of Electronics Industry alone controls at least 140 factories, which produce an estimated 40 million integrated circuits a year. In addition, there are electronics research and manufacturing enterprises operated by the Ministry of Astronautics Industry, the Ministry of Posts and Telecommunications, the Ministry of Machine Building Industry, the Ministry of Light Industry, the Ministry of Public Security, and the Chinese Academy of Sciences. [redacted]

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At present, China manufactures nearly 1,000 types of integrated circuits. Most are small-scale-integration (SSI) or medium-scale-integration (MSI) devices. More sophisticated devices, such as 16K random-access-memory (RAM) units, and 16K erasable-programmable-read-only-memory (EPROM) circuits, and 8- and 16-bit microprocessors are also being manufactured, but in limited quantities and with low production yields. [redacted]

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China's ability to produce integrated circuits in commercial quantities continues to lag behind the US and Japan by five to 10 years.

Table 1

<u>Type of Memory IC</u>	<u>Year First Commercially Available</u>
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	<u>US</u>	<u>Japan</u>	<u>China</u>
1K DRAM	1970	1972	1978
4K DRAM	1974	1975	1981
16K DRAM	1976	1977	1985 (est)
64K DRAM	1980	1980	1989 (est)
256K DRAM	1984	1983	1992 (est)

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China's domestic requirements for microprocessors and advanced logic and memory devices are still being met primarily by imports from Japan and the US. [redacted]

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China's production capabilities in seven major categories of integrated circuits are described below:

TTL Circuits. Transistor-transistor-logic circuits constitute about 50 percent of China's total integrated circuit production. China produces five series of TTL circuits, all based on the Texas Instruments SN74/54 series. Some are produced to military specifications, able to function in temperatures ranging from -55 to +125° C. The Chinese claim that all TTL logic circuits being produced are directly interchangeable with their US-produced counterparts. China is particularly proud of its low-power Schottky (LSTTL) devices, 100 varieties of which are produced--most to military standards--by an integrated circuit plant in China's interior. This plant, the Tianguang Electrical Industry Factory, reportedly supplied some of the circuitry used in China's Galaxy supercomputer. The Tianguang plant of Gansu Province is benefitting from the modernization of its sister plant, the Tianguang factory of Shaoxing, Zhejiang Province. [redacted]

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ECL Circuits. China's emitter-coupled-logic circuits are modeled on the Motorola MC10100 and MC10500 series. These ultra high speed circuits, again produced to military specifications, are also made by Tianguang. In addition, China claims to use these circuits in missile guidance systems, satellite communications equipment, and microwave measurement devices. [redacted]

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General Purpose MOS Logic Circuits. Because of the relatively slow speed and high power consumption of PMOS (positive-channel metal-oxide-semiconductor) devices, China is gradually replacing them with CMOS (complementary MOS) technology. NMOS (negative-channel MOS) technology continues to be used extensively in Chinese microprocessors and memory devices. Mastering the complex CMOS manufacturing process has

been more difficult, but China reportedly produces more than 70 varieties of CMOS circuits, including microprocessors, operational amplifiers, voltage comparators, and digital/analog converters. In 1982, China's domestic sales of CMOS circuits exceeded 3 million units. [redacted]

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Dedicated Circuits. Chinese versions of these circuits-- used in televisions, radios, watches, and other consumer goods-- are mainly based on Japanese devices made by Sanyo, Toshiba, Hitachi, Matsushita, NEC, and others. In recent years, China has purchased equipment for a large number of production lines designed to produce devices for consumer electronics. Many contain refurbished equipment purchased from Japanese or US IC producers, rather than state-of-the-art production technology. Some of the production lines, such as the one at the Jiangnan Radio Equipment and Materials Corporation, may be capable of producing more advanced general purpose integrated circuits than required for color televisions--such as 8-bit microprocessors and 16K memory devices. [redacted]

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Microprocessors. China produces 1-bit CMOS and 4-, 8- and 16-bit NMOS microprocessors. China's 8-bit microprocessors are modeled on Intel's 8080 and Motorola's 6800 series. China claims to be producing single-chip 8-bit processors in at least four different factories, although the chip is most likely significantly larger than its Western counterpart. [redacted]

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In early 1984, China claimed to have begun small-batch production of 16-bit microprocessors at an interior factory subordinate to the Ministry of Astronautics Industry, the Lishan Microelectronics Corporation of Shaanxi Province. The 16-bit processor can be used in real-time control systems in demanding environments; it is designed to operate for long hours in a wide range of temperatures and is resistant to moisture and vibration. [redacted]

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Memory Devices. In 1982, China announced that the Semiconductor Research Institute of the Chinese Academy of Sciences in Beijing had developed a 16K DRAM (dynamic-random-access-memory) chip. At the same time, Beijing made public its ability to produce 4K SRAMs (static-random-access-memory devices) and 8K EPROMs. [redacted]

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A number of institutes are now working to develop very-large-scale-integrated circuit (VLSI) technology. In 1983 and 1984, several Chinese facilities attempted to obtain equipment and information suitable for the production of 256K DRAM circuits.

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Even if China gains access to Western 256K DRAM production technology, the Chinese will probably not produce a prototype 256K DRAM before the end of this decade. Production capability will require several additional years.

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...and Limitations

In laboratory settings, lack of equipment, rather than expertise, is largely responsible for China's delay in producing advanced prototypes. Even with imported high-purity chemicals and materials, the absence of computer-aided-design (CAD) systems and state-of-the-art processing equipment prevents the Chinese from producing VLSIs on the order of a 256K DRAM.

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China's development of prototype 64K and 256K DRAM devices almost certainly requires the acquisition of equipment that will enable the Chinese to pack circuits more densely by using narrower design rules. The equipment generally available in Chinese factories permits the Chinese to produce devices with line widths of 5 to 10 microns, and the Chinese claim to have achieved a 2-micron capability in one institute. In contrast, Western producers routinely use 2-micron geometries and have made substantial progress toward developing a sub-micron capability. Unable to pack circuitry as densely as Western producers, the Chinese have been forced to increase the dimensions of their integrated circuits. Larger chips require larger areas of high-purity silicon wafers to be defect-free. Because Chinese silicon is far from pure enough to satisfy this requirement--even Western silicon producers have tremendous difficulty producing silicon of

sufficient purity--China will eventually have to turn its effort toward obtaining equipment that will enable Chinese factories to shrink the size of their circuitry.

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Another limitation of China's semiconductor industry is the long lead-time required before a developed prototype device moves into factory production. The gap between prototype and commercial production of memory devices, for example, ranges from two to four years and appears to have increased over the last decade, as the sophistication of the devices has risen. In the West, a one or two year gap between prototype development and commercial production--slightly longer for 256K DRAM devices--is the norm.

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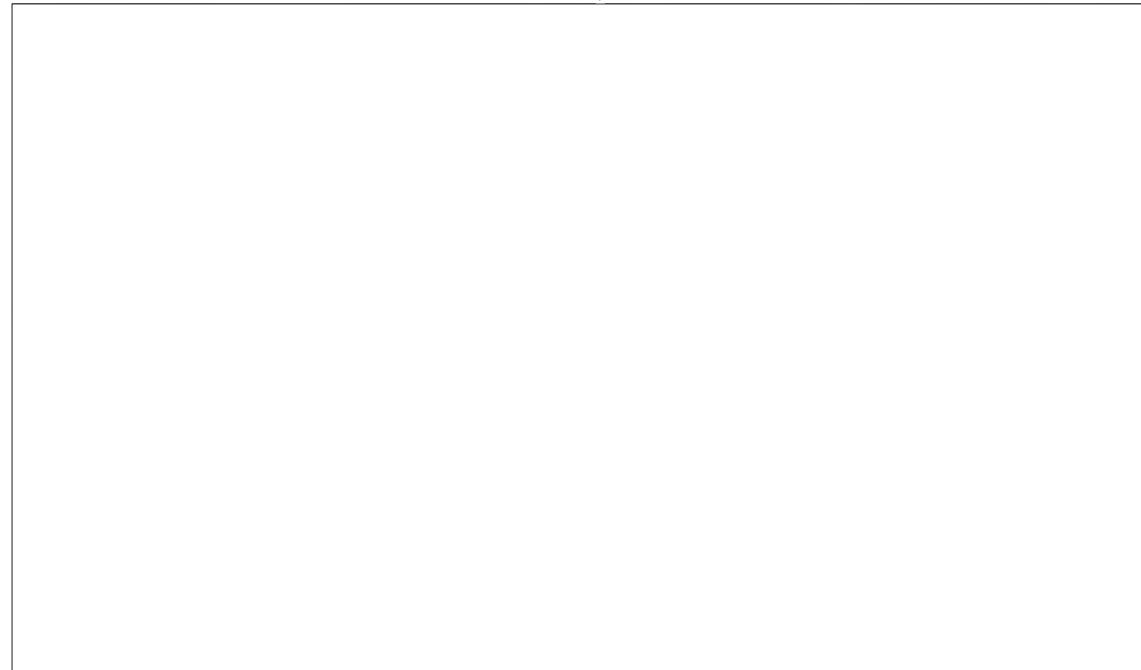
Table 2

China's Development and Production of Memory Devices

<u>Type of IC</u>	<u>Year Developed</u>	<u>Year Produced in Commercial Quantities</u>
1K DRAM	1976	1978
4K DRAM	1979	1981
16K DRAM	1981	1985 (est)
64K DRAM	1984	1989 (est)

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Removing the Obstacles

China is taking steps to improve its ability to develop advanced devices on a laboratory scale as well as to improve production capabilities at its electronics factories. To remove the institutional barriers to advanced electronics production, Beijing is now embarked on a major reform of its entire scientific and technological system. Its aim is to bridge the gap between research findings and commercial production and to improve the flow of technology between factories. To foster the internal transfer of technology, the Chinese leadership is encouraging the mobility of technical personnel, creating financial incentives for institutes to work closely with factories on the development of new products and production techniques, placing a large number of institutes formerly controlled by the Chinese Academy of Sciences under the direct control of industrial ministries, and forming regional corporations, composed of factories and institutes engaged in semiconductor research and production, in major cities.

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To improve material conditions in laboratories and factories, Beijing has embarked on an ambitious program of equipment imports, factory renovation, and investment in key electronics production projects. Because China's goals involve both rapid expansion in the quantity of electronic devices produced for civilian applications and rapid advances in the sophistication of the circuitry produced for military uses, Beijing is using a variety of means to obtain foreign technology and equipment for this sector:

- Cooperative production involving firms from the United States, Japan, and Western Europe. Although most of the emphasis on cooperative production in the

electronics sector is centered on joint venture investment, the Chinese are also promoting compensation trade and kit assembly arrangements.

- Purchases of turnkey plants and design technology for the production of advanced electronic devices. Although contracts for complete production lines have declined overall since 1978, the Chinese now appear more willing to purchase complete sets of equipment in the area of microelectronics.
- Purchases of selected pieces of production and test equipment to modernize existing plants, improve production yields, and produce more sophisticated devices, such as large-scale and very-large-scale-integrated circuits.
- Purchases of used pieces of equipment as well as refurbished complete production lines.

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Although it is difficult to generalize about the method Chinese factories most often select, key projects--frequently related to the production of components to be used in military systems--often involve new, rather than refurbished, equipment. Military-related projects are unlikely to involve any form of cooperative production that would require the presence of foreign managers or advisers. Joint venture projects, imports of used equipment, and purchases of complete production lines are the methods often chosen to boost the production of components to be used in consumer goods or general-purpose computers.

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Among the individual pieces of wafer fabrication equipment China most actively seeks to import are:

- Microprocessor-controlled Czochralski furnaces for growing low-defect single-crystal silicon ingots.
- Molecular-beam epitaxial reactors for growth of a layer of pure silicon (or gallium arsenide) on wafer surfaces.
- Computer-aided design software, pattern generators and compilers, and graphics systems for developing mask designs.
- Electron beam lithographic equipment for producing masks.
- Projection mask alignment systems for use in photolithography.
- X-ray lithographic equipment.
- Ion implanters.

-- Plasma etching reactors.
-- Magnetron sputtering equipment.
-- Wafer probers for circuit testing.
-- Automated gold wire bonding equipment.
-- Equipment for producing multilayer printed circuit
boards.

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The Management of China's Electronics Industry

This paper provides background on the organizations involved in the planning, management, and foreign trade of China's electronics sector.

Leading Group for the Invigoration of the Electronics Industry

In September 1984, Beijing reorganized and renamed the Leading Group for Computers and Large-Scale Integrated Circuits, which had been charged since 1983 with overseeing the development of these products. At the same time, Vice Premier Li Peng replaced Vice Premier Wan Li as the chairman of the Leading Group. In addition, the membership of the Leading Group was broadened. Ranking officials from the State Economic Commission, the State Science and Technology Commission, the National Defense, Science Technology and Industry Commission, the People's Bank of China, and the Ministries of Electronics, Machine Building, Post and Telecommunications, Railroads, and Water Resources and Electric Power all serve on the new leading group. (See Figure 1)

The Leading Group for the Invigoration of the Electronics Industry is charged with strengthening centralized leadership over electronics and information enterprises. Its functions include: formulating development goals and general strategies; approving key plans and supervising their implementation; coordinating research and production, and examining and approving the imports planned for major projects.

The new Leading Group has defined the strategic goal of the electronics industry as developing "microelectronics technology as the foundation, and computer and telecommunications equipment

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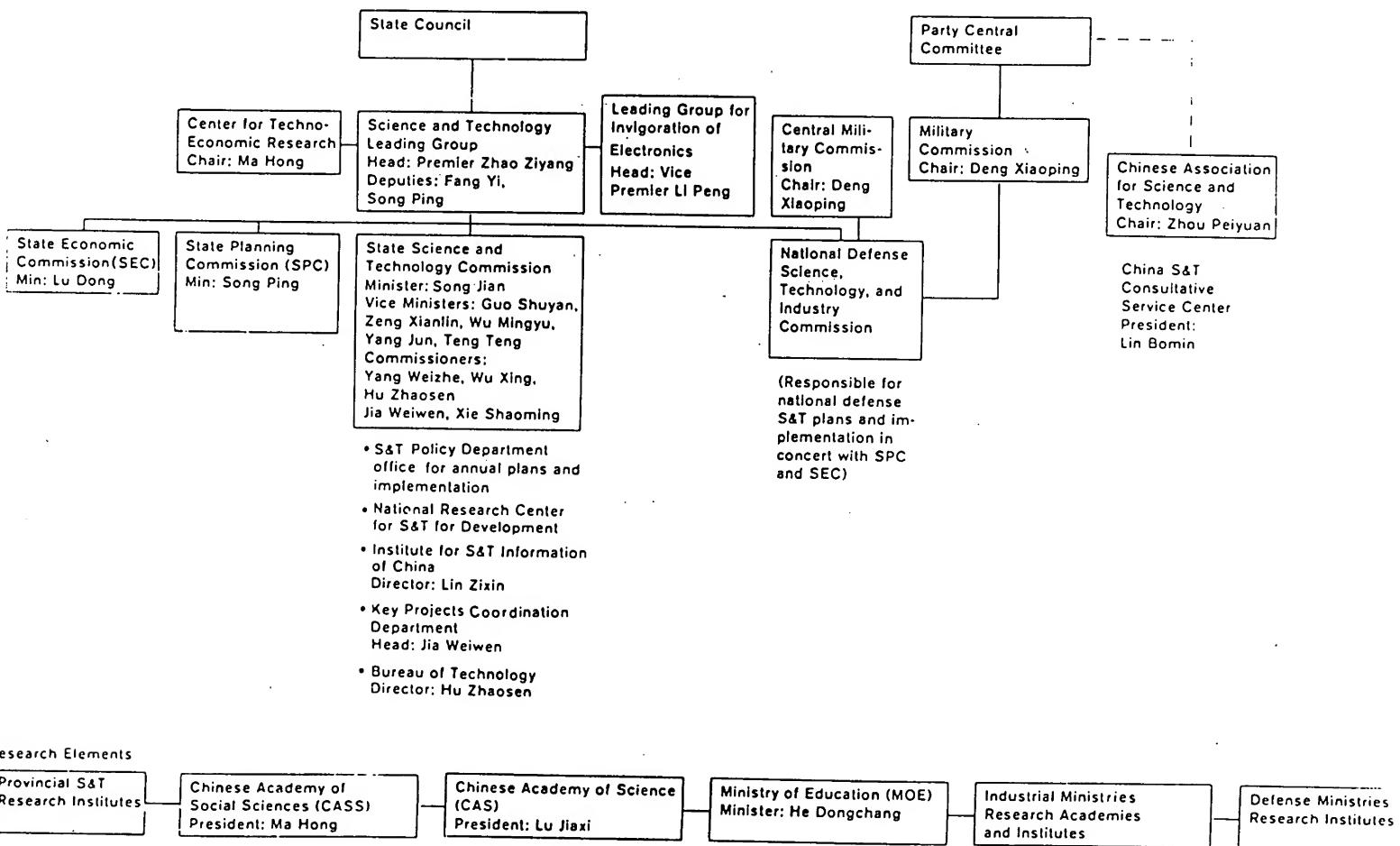
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Figure 1

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China's Research and Development Community

Policy Elements



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as the main body." The Chinese press reports this goal has been adopted by the State Council and will be emphasized in China's Seventh Five Year Plan (1986-1990), soon to be announced.

The Ministry of Electronics Industry

MEI, formerly the Fourth Ministry of Machine Building, coordinates one of China's most rapidly developing industrial sectors. The Ministry directs applied electronics research and manages the development and production of electronics products for both civilian and military needs.

MEI controls some 2,400 enterprises employing more than 90,000 engineers and technicians and one million additional non-technical personnel. Although MEI manages some of these enterprises directly, control of most of them has been delegated to provincial, municipal, and county organizations, which receive planning guidance from the Ministry. In addition to MEI and to provincial and municipal authorities, the Ministries of Posts and Telecommunications, Astronautics, Machine Building, Light Industry, and the Chinese Academy of Sciences all produce electronic goods for their own uses.

Industrial bureaus subordinate to the MEI include:

- **Bureau of Radar Industry** - responsible for manufacturing various ground, weather, and airborne and shipboard radars.
- **Bureau of Communications, Broadcast and Television** - responsible for communication, navigation and broadcasting equipment, television sets, radios, and tape recorders.
- **Bureau of Computer Industry** - responsible for manufacturing computers, peripherals and related equipment; controls research, production, imports, and product distribution for a number of institutes and factories; provides staff support for and policy recommendations to MEI and the Leading Group; controls China Software Technology Corporation (CSTC) and China Computer Technical Service Corporation (CCTSC)--companies that form joint ventures with foreign firms for software development and for computer maintenance and service.
- **Bureau of Electronic Components and Devices** - responsible for manufacturing vacuum tubes, semiconductor devices, integrated circuits, electronic instruments, special processing equipment, and electronic materials.

Electronics research controlled by the Ministry comes under the direction of four research academies. Institutes conduct research for the academies. At least 55 such institutes are subordinate to the MEI.

The MEI also controls several specialized import-export corporations to acquire equipment and technology from foreign sources. These include the China Electronics Import-Export Corporation (CEIEC) and the China National Electronic Devices Corporation (CNEDC). CEIEC has branches in Guangzhou, Shenzhen, Shanghai, Tianjin, Beijing, and most provinces. (See Figure 2)

Inter-Ministerial Regional Corporations

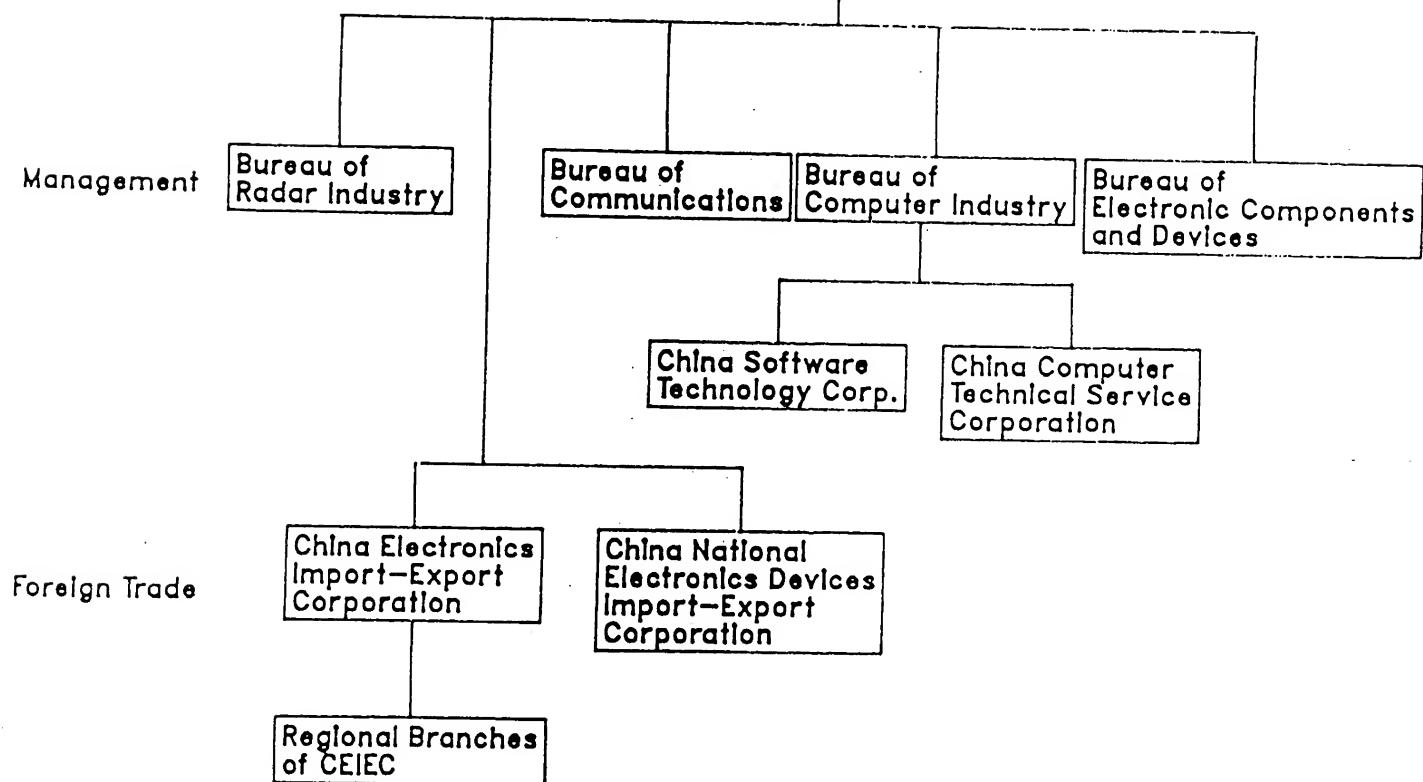
Regional electronics corporations, composed of factories and institutes engaged in the production of similar goods, have been or are being formed in major cities. These regional combines are being formed to reduce the duplication of research being done by various institutes, to coordinate factories' imports of equipment and materials, to facilitate the sharing of technical information between institutes and factories, and to ensure that components, computers, and telecommunications equipment are compatible with one another. Examples include:

- **The Nanjing Radio Company**, an integrated complex composed of 37 factories, and provincial and municipal authorities.
- **The Shanghai Software Technological Development Center**, which comprises six universities, two institutes, and various municipal entities.
- **The Shanghai Computer Company**, which includes two computer factories, a telecommunications factory, an instrument factory, a research institute and municipal organizations.
- **The Shenyang Computer United Corporation**, which includes 11 production and research units.

Formation of such regional corporations is only one of the means Beijing is using to remove the institutional barriers to progress in the production of electronic goods. Beijing is now embarked on a major reform of its entire scientific and technological system, aimed at improving the flow of technology between institutes and factories, between military and civilian sectors, and among factories spread across several ministries. To foster the internal transfer of technology, the Chinese leadership is encouraging the mobility of technical personnel, creating financial incentives for institutes to work closely with factories on the development of new products and production techniques, and placing a large number of institutes formerly controlled by the Chinese Academy of Sciences under the direct control of industrial ministries. All sectors are involved in this effort, but the electronics industry is the focal point for many of the reforms.

Figure 2

Ministry of Electronics Industry



The Buyers

A large and increasing number of corporations are involved in China's imports of semiconductor production technology and equipment. At the national level, there are several trading corporations under the Ministry of Foreign Economic Relations and Trade, the Ministry of Electronics Industry, and each of the defense industrial ministries. Buying corporations are also operated by the Chinese Academy of Sciences, the National Defense, Science, Technology and Industry Commission, and the State Science and Technology Commission. (See Table 1.)

In addition to the national level trade corporations, the current decentralization of China's foreign trade has given rise to a number of regional or municipal-level trade organizations. The number of local traders is multiplying rapidly, and the value of the purchases many are authorized to make--as well as their authority to sign cooperative production agreements--remains unclear. The regional corporations most actively involved in electronics procurement are located in Shanghai, Tianjin, and the Shenzhen Special Economic Zone.

Table 1

National Electronics Trade Corporations

<u>Corporation</u>	<u>Subordination</u>
China Electronics Import-Export Corporation	Ministry of Electronics Industry (MEI)
China National Electronic Devices Corporation	MEI
China Great Wall Industry Corporation	Ministry of Astronautics Industry (MOAI)
China Precision Machinery Import-Export Corporation	MOAI
China Yanshan Science and Technology Corporation	--
Xiaofeng Technology and Equipment Corporation	--
Xinshidai Company	National Defense Science Technology and Industry Commission (NDSTIC)
Oriental Scientific Instruments Import-Export Corporation	Chinese Academy of Science
China Scientific Instruments and Materials Corporation	State Science and Technology Commission
China Electronic System Engineering Corporation	Ministry of National Defense
China National Instruments Import-Export Corporation	Ministry of Foreign Economic Relations and Trade (MFERT)
China National Technology Import-Export Corporation	MFERT